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Response of Estuarine Diatom Assemblages to Ultraviolet-B Radiation (290-320 nm)

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by

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The results indicated that daily exposure to enhanced levels of UV-B radiation was associated with a decrease in species diversity of benthic diatom assemblages during all experiments after four weeks of growth. However, changes in taxonomic structure were not accompanied by a significant depression in chlorophyll a concentration, biomass, or radiocarbon uptake. In fact, in some experiments enhanced levels of UV-B radiation appeared to have a stimulatory effect on the latter parameters.

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ABSTRACT

Artificial substrates colonized by diatoms from Yaquina Estuary, Oregon, were exposed to solar visible radiation and three levels of ultraviolet radiation (UV-B, 290-320 nm). Flow-through microcosms were constructed inside a glasshouse to serve as chambers for the artificial substrates. The artificial substrates were sampled during three spring/summer experiments. Chlorophyll a concentration, biomass (ash-free dry weight), primary productivity (radiocarbon uptake), and community composition were the parameters measured biweekly for each four-week experimental period.

The results indicated that daily exposure to enhanced levels of UV-B radiation was associated with a decrease in species diversity of benthic diatom assemblages during all experiments after four weeks of growth. However, changes in taxonomic structure were not uniformly accompanied by a significant changes in chlorophyll a concentration, biomass, or radiocarbon uptake.

INTRODUCTION

Numerous investigators have measured a depression in primary productivity and growth of marine phytoplankton, and an alteration of phytoplankton community structure following exposure to UV-B radiation (Lorenzen 1979; Calkins and Thordardottir 1980; Smith and Baker 1980; Smith et al. 1980; Worrest et al. 1981). In contrast, there have been relatively few studies regarding the response of marine benthic diatoms to UV-B radiation. This may be a serious oversight considering the magnitude of primary production by marine benthic microflora. In estuaries and coastal wetlands the epibenthic primary productivity often exceeds that of the phytoplankton and could be an important component of estuarine food webs (Grontved 1960; Leach 1970; Cadée and Hegeman 1974; Matheke and Horner 1974). Benthic diatoms are also a major carbon source for numerous marine and estuarine invertebrates, and their growth on sediment surfaces promotes sediment binding and stabilization (Holland et al. 1974; Wetzel 1977; Frostick and McClave 1979).

Worrest et al. (1978) quantified changes in biomass and community structure of benthic estuarine diatom assemblages following exposure of the assemblages to UV-B radiation in a laboratory microcosm. In a second laboratory study Thomson et al. (1980) measured a depression in the growth rate of a common intertidal epilithic diatom following exposure of the diatoms to UV-B radiation. However, extrapolating results from these and other laboratory studies concerning UV-B effects on algal growth and photosyn-

thesis to natural systems is difficult. There is overwhelming evidence for substantial interactions between UV-B radiation and longer wavelength radiation (e.g., Teramura 1982). For example, when subjected to UV-B radiation there is a greater depression in terrestrial plant photosynthesis under low levels of visible irradiance than under higher levels of visible irradiance (Sisson and Caldwell 1976; Teramura et al. 1980).

The purpose of the present study was to measure the structural and functional response of estuarine benthic diatom assemblages exposed to UV-B radiation along with natural levels of photosynthetically active radiation.

MATERIALS AND METHODS

The study was repeated three times during the spring and summer of 1981. Each experiment was conducted using artificial substrates maintained in three replicate microcosms. The microcosms were housed within a glasshouse located at Oregon State University's Hatfield Marine Science Center in Newport, Oregon (44°37'N).

Each artificial substrate consisted of a rectangular (30 x 5 cm) piece of Mylar 'D' polyester film (0.13 mm thickness, DuPont) attached to a matching (30 x 5 cm) polyvinylchloride (PVC) base. The substrates were anchored 10.2 cm apart and 2.5 cm off the bottom of the microcosm using two parallel lengths of PVC pipe. The depth of the water covering the substrates was 9 cm. Each complete assembly of artificial substrates and PVC pipe was centered lengthwise and attached to each end of a microcosm. The microcosms had water capacities of about 130 l. The microcosms were placed end-to-end along the northern wall of the glasshouse. Seawater entered each microcosm through a vertical inlet located midway along the rear side of each microcosm. There were two outlets per microcosm, one at each end of the side opposite the inlet.

Initially, raw seawater from lower Yaquina Bay was pumped continuously through the microcosms. After one-to-three days the raw seawater was turned off and filtered seawater was used for the remainder of an experiment. The filtered seawater consisted of sand-filtered raw seawater which was then exposed to germicidal ultraviolet radiation. The raw seawater provided an initial seed culture while the filtered seawater reduced the introduction of new populations of microorganisms and prevented the buildup of sediment and macroalgal fragments. Flow rates for raw seawater and filtered seawater were the same in each microcosm during an experiment and ranged from 0.4 l min^{-1} to 1.2 l min^{-1}.

Water temperature was recorded continuously (Partlow Recording Thermometer, Model RFT) and nutrients (orthophosphorous, reactive silica, nitrite- and nitrate-nitrogen) were monitored weekly in each microcosm. The daily mean temperature of the water during the experiments ranged from 13°C to 21°C. The temperature in the microcosms was generally higher and the range larger than that measured in lower Yaquina Bay (thermistor sensor, 4.0 m below MLLW), but consistent overlaps did occur between the two temperature ranges. Salinity varied from 10°/oo to 30°/oo during all experiments. Salinity in lower Yaquina Bay ranges from as low as low as 8°/oo in the winter during high freshwater discharge, to 35°/oo in the summer during upwelling.

The low-iron glass (Sunadex, ASG Industries) of the glasshouse filtered out most of the solar ultraviolet radiation in the UV-B waveband and absorbed about 10% of the natural, visible radiation. Therefore a lamp/filter system was used to simulate solar UV-B irradiances for this study. Each lamp fixture of the lamp/filter system held one Westinghouse FS-40 fluorescent sunlamp and one deluxe-white 40 W fluorescent lamp (Vita-Lite, Duro-Test Corporation). Five lamp fixtures were positioned end-to-end and centered lengthwise above the row of artificial substrates. All lamps were preburned before use and the duration of sunlamp exposure was 4.0 to 6.0 h each day, centered around solar noon.

The ultraviolet irradiance at the surface of the microcosms was measured with an Optronic Laboratories Model 742 spectroradiometer which had been characterized at the U.S. National Bureau of Standards. The spectroradiometer was coupled with an Optronic Model 755 data acquisition system for data reduction and digital printout. Supplemental visible irradiance from the fluorescent lamps was measured by a quantum sensor (Li-Cor Model LI-192SB; 400-700 nm response) and averaged 2.5 E m^{-2} d^{-1} at the surface of each microcosm. The total solar irradiance was measured daily with an integrating quantum sensor (Li-Cor Models LI-550B and LI-190SB; 400-700 nm response). Total solar irradiance varied between 10.1 to 45.9 E m^{-2} d^{-1}. The mean daily solar irradiance for each of the three experiments was 26.1, 34.4 and 31.2 E m^{-2}.

Two UV-B irradiance treatments for each experiment were established by using two different thicknesses of cellulose acetate film (0.13 mm and 0.25 mm) with the lamp fixtures. The cellulose acetate film (CA) absorbed wavelengths shorter than 290 nm. The CA was partially photodegraded before use and was changed weekly to compensate for the continued photodegradation that occurred under the fluorescent sunlamps. A third treatment utilizing Mylar 'D' (0.18 mm thickness) polyester film, which absorbs UV-B radiation, was used as a control for potential UV-B effects. The Mylar filters were also changed weekly to maintain initial irradiance levels. All three treatments were represented in each of the three microcosms.

Caldwell's (1971) generalized plant action spectrum was used as the basis for simulation of current and enhanced levels of biologically effective UV-B radiation. Worrest et al. (1981) found this weighting function was the best fit of those tested for phytoplankton response of chlorophyll _a_ concentration and radiocarbon uptake to UV-B radiation. For comparative purposes two other biological weighting functions were considered: an action spectrum for photoinhibition of isolated chloroplasts (Jones and Kok 1966) and a DNA action spectrum (Setlow 1974). The reference wavelengths used in the present study for normalization of the Caldwell (1971), Jones and Kok (1966) and Setlow (1974) weighting functions were the same as those employed by Green and Miller (1975) and Smith and Baker (1979).

Experimental UV-B levels of exposure were selected to approximate an incident solar UV-B irradiance at standard (0.32 atm-cm) ozone levels and under conditions of reduced atmospheric ozone. The artificial substrates exposed to UV radiation filtered through a 0.25 mm thickness of CA (= LOW) received daily effective doses which simulated predicted incident UV-B levels at 44°37'N latitude for 0.32 cm ozone, 0.0 albedo and 2.0 aerosol scaling factor at sea level (parameters of the model described by Green et al. 1980). The daily effective dose under the 0.13 mm thickness of CA (=HIGH) was comparable to a 20-33% reduction in ozone thickness in the

model previously described (see 'MODEL' in Table 1).

Table 1. Absolute (290-320 nm) and biologically weighted UV irradiances and daily doses transmitted by 0.13 mm CA (HIGH), 0.25 mm CA (LOW) and Mylar (CONTROL) filters in each experiment. The predicted absolute and biolpgically weighted UV irradiances (Solar Noon, Global) and daily doses near the midpoint of each experiment are listed in the table under MODEL. These data are from a computer model based on Green et al. (1980) and correspond to 44.37°N latitude at sea level, 0.32 atm-cm ozone thickness, 0.0 albedo, and a 2.0 aerosol scaling coefficient.

		Irradiance (mW m^{-2})		Daily Dose (J m^{-2})	
Experiment	Treatment	Plant[a]	Absolute	Plant	Absolute
29 April-	MODEL	61.8	3179	1266	8.85×10^4
28 May	LOW	66.6	951	1366	1.97×10^4
	HIGH	119.9	1511	2482	3.13×10^4
	CONTROL	0.014	26	0.3	0.05×10^4
10 June-	MODEL	70.6	3570	1512	9.00×10^4
9 July	LOW	66.6	951	1439	2.05×10^4
	HIGH	119.9	1511	2590	3.26×10^4
	CONTROL	0.014	26	0.3	0.05×10^4
13 July-	MODEL	65.0	3286	1354	8.10×10^4
12 August	LOW	66.6	951	1319	1.88×10^4
	HIGH	119.9	1511	2374	2.99×10^4
	CONTROL	0.014	26	0.3	0.05×10^4

[a]Plant biological weighting function based on Caldwell (1971).

'LOW' experimental UV-B irradiance levels were equivalent to the effective UV-B irradiance typically observed at noon near the midpoint date of each experiment. Likewise, the duration of UV-B exposure was chosen to approximate the daily effective UV-B dose observed near the midpoint date of each experiment (Table 1). It was recognized that solar UV-B irradiance has a diel and daily variation, but a variable experimental UV-B irradiance and variable daily dose were impractical during the course of each experiment in this study.

The diatom assemblages (periphyton) were analyzed at two-week intervals for chlorophyll a, primary productivity (radiocarbon uptake), biomass (ash-free dry weight) and community composition. All four parameters were measured from one substrate, and the measurement of each parameter was based on a 30 cm^2 surface area. There were two substrates available per treatment at each sampling date from one microcosm. The artificial substrates were not replaced in the microcosms after they had been removed for sampling.

Chlorophyll a concentration was calculated according to Lorenzen (1967). For biomass determination, the periphyton was scraped off the artificial substrates and desiccated on tared, preashed Whatman 4.5 GF/C filters. The filters were weighed, ashed at 475°C for 1.5 h, and then weighed again to complete the ash-free dry-weight calculation. Primary productivity was measured using the traditional ^{14}C light and dark bottle technique (Steemann Nielsen 1952). Radiolabelled periphyton were incubated in sealed Vycor (Corning Glass) vessels for 3 h while submerged in the microcosms. Vycor absorbs and reflects less than 30% of the UV-B radiation. Alkalinity was measured with the aid of a YSI salinity meter (Model 33 SCT, Yellow Springs) and an analog pH meter (Model 399A, Orion Research). Total carbonate content and radiocarbon uptake was calculated according to Strickland and Parsons (1972).

Permanent slides for community structure analysis were first prepared by digesting the material in cold concentrated nitric acid. The cleaned diatom suspensions were then mounted on microscope slides with Hyrax (Custom Research and Development, Inc.) using the procedure outlined in Patrick and Reimer (1966). Samples were taken at each sampling date from each microcosm and then pooled by treatment for community structure analysis. Each slide therefore represented a pooled sample from all microcosms. The prepared slides were examined at 1000x with a Zeiss standard RA microscope. Approximately 500 frustules were counted from each sample. Taxa were identified to species using standard taxonomic references and regional publications (Peragallo and Peragallo 1897-1908; Hustedt 1930, 1955; Cupp 1943; Hendey 1964; Patrick and Reimer 1966, 1975; Riznyk 1973; Amspoker 1977). To aid in the identification of problematic, usually very small taxa, samples of cleaned diatom suspensions were also examined under a Phillips EM 200 transmission electron microscope.

Several different species composition parameters and related statistics were calculated for each slide as described in McIntire and Overton (1971). The Information Measure H" (Shannon and Weaver 1949) was calculated for one index of diversity. H" ranges from $\log_2 S$, where S is the total number of species in the sample, if every taxon is equally common, to 0 ($\log_2 1$), if all individuals belong to a single taxon. H" is a biased estimator of the population value of the diversity (or information) per individual (H'). However, the bias becomes negligible at sample sizes of 500 or more (McIntire and Overton 1971). The variance of H" was calculated according to the formula presented in Pielou (1966). Conditional maximum and minimum values of H" based on the observed number of species in a sample are used to calculate a redundancy index (R'). R' is a useful measure of the relative degree of species dominance in the sample. Values of R' range from 0, when the individuals are equally distributed among the taxa, to 1, when all but one taxon are represented by a single individual. The difference measure (D_{hk}) of MacArthur (1965) was calculated to compare pairs of diatom assemblages. If the two assemblages are identical in species composition and relative abundance, D_{hk} has a minimum of 1, and if the two assemblages possess no taxa in common, D_{hk} has a maximum of 2.

Calculations for analysis of diversity, redundancy and resemblance measures were completed on a Control Data Corporation 170/720 Cyber computer at the Oregon State University Computer Center using the *AIDONE and *AIDN programs. Analyses of variance of biomass, chlorophyll a concentration and radiocarbon uptake were calculated with a PDP 11/70 Digital computer at the Corvallis Environmental Research Laboratory, U.S. Environmental Protection

Agency, using the BMDP statistical package.

RESULTS

Species diversity consistently decreased with time under HIGH levels of UV-B radiation in all of the experiments. The species composition of the diatom assemblages exposed to UV-B radiation was characterized by a higher percentage of filamentous and tube-dwelling species when compared to diatom assemblages growing under CONTROL UV-B conditions (Tables 2-4). At the end of the experiments the order of increasing redundancy was CONTROL-LOW-HIGH (Table 5). Matrices of difference (D_{hk}) values, calculated for comparison of the diatom assemblages pooled by experiment, also indicated that at the end of each experiment, the highest D_{hk} values were found for comparisons between diatom assemblages collected from HIGH UV-B exposed substrates and those sampled from CONTROL exposed substrates.

With regard to the non-taxonomic parameters, daily exposure to enhanced UV-B radiation did not appear to have a consistently significant effect upon biomass, chlorophyll a concentration, or radiocarbon uptake; although in one experiment the chlorophyll concentration did significantly increase with increased exposure to UV-B radiation.

DISCUSSION

Marine algae differ in their tolerance of ultraviolet radiation, some species being sensitive to natural levels of solar ultraviolet radiation. As reviewed by Worrest (1982), the response of marine phytoplankton communities to UV-B radiation is variable, but the general trend is a depression of primary productivity and growth, and an alteration of community structure with increasing UV-B dose. These results have been determined under both field and laboratory conditions. The response of diatom communities in benthic marine systems to UV-B radiation is a depression of growth rate and an alteration of community structure with increasing UV-B dose (Van Dyke and Thomson 1975; Worrest et al. 1978; Thomson et al. 1980). These results were derived primarily from laboratory microcosms, and have not been corroborated under field conditions. For predicting events in natural ecosystems, the utility of UV-B radiation studies, based on results from laboratory microcosms, is affected by (1) the simplification imposed by the use of microcosms, (2) the attenuation of UV-B radiation in natural waters, and (3) the ratio of photosynthetically active radiation (PAR) to UV-B radiation available to the test organisms.

The microcosms in the present study simulated denuded estuarine environments without tidal influence. The success of a particular taxon of diatoms on a substrate depends on its density in the species pool, its ability to attach to the substrate, its tolerance of the environment, and its ability to compete and reproduce (McIntire and Overton 1971). In natural estuarine ecosystems, benthic diatoms are continuously being replaced by other taxa from the open water or nearby occupied areas. In the present study, recruitment from the inflowing seawater was limited to the first few days in each experiment. Therefore, changes in the abundance of diatom taxa during each experiment was more a result of species interactions and responses to the environment than through invasion by new species from the species pool in Yaquina Estuary.

Table 2. A list of the dominant diatom taxa from Experiment I (29 April - 28 May) and the percentage composition of those species within each assemblage (≧ 5% of the total enumerated per treatment). Treatment HIGH, LOW and CONTROL correspond to 0.13 mm CA, 0.25 mm CA and Mylar filters, respectively. Samples were collected after two and four weeks of growth.

Treatment	Taxon	Percentage Composition
HIGH (2 weeks)	Fragilaria striatula var. californica Grun.	44
	Cylindrotheca closterium (Ehr.) Reiman & Lewin	18
	Skeletonema costatum (Grev.) Cl.	9
	Nitzschia fundi Chol.	6
	Navicula diserta Hust.	5
LOW (2 weeks)	Fragilaria striatula var. californica Grun.	50
	Cylindrotheca closterium (Ehr.) Reiman & Lewin	11
	Nitzschia fundi Chol.	7
	Navicula diserta Hust.	6
	Berkeleya rutilans (Trent.) Grun.	6
CONTROL (2 weeks)	Fragilaria striatula var. californica Grun.	54
	Cylindrotheca closterium (Ehr.) Reiman & Lewin	18
	Skeletonema costatum (Grev.) Cl.	10
	Nitzschia fundi Chol.	5
HIGH (4 weeks)	Fraglilaria striatula var. californica Grun.	54
	Melosira nummuloides (Dillw.) Ag.	14
	Cylindrotheca closterium (Ehr.) Reiman & Lewin	8
	Navicula ostrearia (Gaillon) Turpin in Bory	5
LOW (4 weeks)	Fragilaria striatula var. californica Grun.	34
	Navicula ostrearia (Gaillon) Turpin in Bory	13
	Cylindrotheca closterium (Ehr.) Reiman & Lewin	8
	Nitzschia longissima var. reversa (Breb.) Grun.	7
	Navicula diserta Hust.	6
CONTROL (4 weeks)	Fragilaria striatula var. californica Grun.	26
	Navicula ostrearia (Gaillon) Turpin in Bory	19
	Nitzschia longissima var. reversa (Breb.) Grun.	9
	Melosira nummuloides (Dillw.) Ag.	9
	Berkeleya rutilans (Trent.) Grun.	5

Table 3. A list of the dominant diatom taxa from Experiment II (10 June - 9 July) and the percentage composition of those species within each assemblage (≥ 5% of the total enumerated per treatment). Other conditions are the same as in Table 2.

Treatment	Taxon	Percentage Composition
HIGH (2 weeks)	Nitzschia americana Hasle	16
	Cylindrotheca closterium (Ehr.) Reiman & Lewin	11
	Berkeleya rutilans (Trent.) Grun.	9
	Melosira nummuloides (Dillw.) Ag.	9
	Nitzschia fundi Chol.	8
	Thalassiosira No. 1	8
	Chaetoceros No. 1	7
	Nitzschia longissima (Breb.) Grun. f. parva	5
	Amphipora hyalina Eulenstein ex V.H.	5
LOW (2 weeks)	Melosira nummuloides (Dillw.) Ag.	20
	Nitzschia americana Hasle	17
	Thalassiosira No. 1	7
	Nitzschia fundi Chol.	6
	Chaetoceros No. 1	6
	Skeletonema costatum (Grev.) Cl.	5
CONTROL (2 weeks)	Nitzschia americana Hasle	20
	Cylindrotheca closterium (Ehr.) Reiman & Lewin	14
	Thalassiosira No. 1	9
	Nitzschia fundi Chol.	6
	Chaetoceros No. 1	6
	Amphiprora hyalina Eulenstein ex V.H.	5
	Melosira nummuloides (Dillw.) Ag.	5
	Nitzschia longissima (Breb.) Grun. f. parva	5
	Skeletonema costatum (Grev.) Cl.	5
HIGH (4 weeks)	Berkeleya rutilans (Trent.) Cl.	35
	Melosira nummuloides (Dillw.) Ag.	31
	Amphiprora hyalina Eulenstein ex V.H.	6
	Amphora micrometra Giffen	5
LOW (4 weeks)	Melosira nummuloides (Dillw.) Ag.	45
	Berkeleya rutilans (Trent.) Grun.	19
	Amphora micrometra Giffen	5
CONTROL (4 weeks)	Berkeleya rutilans (Trent.) Grun.	28
	Melosira nummuloides (Dillw.) Ag.	19
	Amphiprora hyalina Eulenstein ex V.H.	7
	Amphora tenerrima Aleem ex Hust.	7
	Bacillaria paxillifer (Mull.) Hendey	7
	Amphora micrometra Giffen	6
	Nitzschia fundi Chol.	5

Table 4. A list of the dominant diatom taxa from Experiment III (13 July - 12 August) and the percentage composition of those species within each assemblage (≥ 5% of the total enumerated per treatment). Other conditions are the same as in Table 2.

Treatment	Taxon	Percentage Composition
HIGH (2 weeks)	Melosira nummuloides (Dillw.) Ag.	23
	Fragilaria striatula var. californica Grun.	21
	Thalassiosira No. 2	16
	Nitzschia fundi Chol.	5
LOW (2 weeks)	Melosira nummuloides (Dillw.) Ag.	34
	Fragilaria striatula var. californica Grun.	21
	Thalassiosira No. 2	8
	Skeletonema costatum (Grev.) Cl.	7
	Nitzschia fundi Chol.	6
CONTROL (2 weeks)	Melosira nummuloides (Dillw.) Ag.	41
	Skeletonema costatum (Grev.) Cl.	11
	Fragilaria striatula var. californica Grun.	10
	Thalassiosira No. 2	8
HIGH (4 weeks)	Melosira nummuloides (Dillw.) Ag.	60
	Fragilaria striatula var. californica Grun.	12
	Amphora micrometra Giffen	5
	Nitzschia fundi Chol.	5
LOW (4 weeks)	Melosira nummuloides (Dillw.) Ag.	51
	Amphora micrometra Giffen	9
	Amphiprora hyalina Eulenstein ex V.H.	5
CONTROL (4 weeks)	Melosira nummuloides (Dillw.) Ag.	38
	Navicula diserta Hust.	9
	Amphora micrometra Giffen	8
	Amphiprora hyalina Eulenstein ex V.H.	8
	Fragilaria striatula var. californica Grun.	7
	Nitzschia fundi Chol.	6
	Berkeleya rutilans (Trent.) Grun.	5

Table 5. The number of individuals (N), number of taxa (S) and expressions of diversity and dominance for diatom assemblages collected from artificial substrates. The Information Index (H") is expressed as bits per individual and R' is a measure of redundancy. Treatment HIGH, LOW and CONTROL correspond to 0.13 mm CA, 0.25 mm CA and Mylar filters respectively. Variance of H" ranged from 0.013 to 0.029.

Time	Treatment	N	S	H"	R'
29 April-28 May					
2 weeks	HIGH	500	29	2.03	0.452
	LOW	500	30	2.03	0.450
	CONTROL	500	28	1.99	0.457
4 weeks	HIGH	500	24	1.77	0.496
	LOW	501	31	2.45	0.329
	CONTROL	490	27	2.42	0.300
10 June-9 July					
2 weeks	HIGH	500	31	2.80	0.212
	LOW	500	35	2.75	0.264
	CONTROL	500	30	2.77	0.210
4 weeks	HIGH	492	31	2.01	0.475
	LOW	500	27	2.06	0.423
	CONTROL	501	31	2.47	0.320
13 July-12 August					
2 weeks	HIGH	500	34	2.53	0.326
	LOW	500	32	2.30	0.386
	CONTROL	500	33	2.31	0.392
4 weeks	HIGH	500	26	1.64	0.559
	LOW	498	30	2.10	0.436
	CONTROL	500	33	2.35	0.377

Diatom taxa and values for species composition for the diatom communities that developed on artificial substrates in the present study were similar to field data available concerning the community properties of littoral diatom assemblages from Yaquina Bay (McIntire and Overton 1971; Moore and McIntire 1977). There was some variation in density and occurrence of specific diatom taxa. It is not clear how the overall variance inherent in the behavior of replicate microcosms should be viewed and few guidelines exist as to how closely, and with respect to which parameters a microcosm

must follow the natural system to be considered an acceptable model (Pilson and Nixon 1980).

Marine microcosms generally use small volumes of water and would be limited to modeling conditions representative of the first few meters of the sea surface. The penetration of UV-B radiation into the upper few meters of natural waters varies widely depending on the particulate and organic content of the water. Maximum penetration of UV radiation occurs in ocean waters having a minimum concentration of dissolved organic matter. UV-B radiation (e.g., 310 nm) is limited to approximately the upper 10% of the euphotic zone for coastal waters before being reduced to 1% of its surface irradiance (Jerlov 1976). This corresponds to roughly the upper 15 m in low organic water and 1 or 2 m in productive coastal waters.

Despite the differences in UV-B irradiance treatments and PAR levels between this study and previous studies, one common result was observed. The most consistent response by the diatom assemblages to UV-B radiation was a decrease in species diversity following exposure to enhanced levels of UV-B radiation. There are several implications of an alteration in the community structure of benthic diatom assemblages. Marine benthic diatoms are an important carbon source for invertebrate grazers and detritus feeders (Wetzel 1977). Benthic algal production, estimated at 20% to 25% of angiosperm production, is the second major primary producer and source of fixed carbon in salt marsh and estuarine ecosystems (Pomeroy 1959; Gallagher and Daiber 1974). Unlike the detrital input from angiosperm production, benthic microalgae represent a seasonally available and readily utilizable source of carbon and nutrients to primary consumers. Diatoms found in the stomach of gastropods are primarily motile forms. A shift in community composition to filamentous, non-motile forms could decrease the quantity and quality of food available to these primary consumers (Connor and Edgar 1982).

In summary, decreased community diversity and shifts in community structure did occur in this study. However, these taxonomic structure changes did not result in reduced levels of primary productivity, biomass, or chlorophyll accumulation patterns of the diatom assemblages. These results support Caldwell's (1981) conclusion that, in natural plant communities, a change in species composition rather than a decrease in net production might be a more likely result of a decreased ozone layer with the concomitant increase in UV exposure. Results from this study when compared to laboratory studies indicate a need for field validation of studies regarding UV-B effects on benthic marine plant communities.

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